Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

Nonresidential Drain Water Heat Recovery

2022-NR-DWHR-F | Nonresidential Water Heating | September 2020 FINAL CASE REPORT

Prepared by Energy Solutions

Please submit comments to info@title24stakeholders.com.

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Table of Contents

List of Tables

List of Figures

Executive Summary

If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison, – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this Final CASE Report is to present a code change proposal for nonresidential drain water heat recovery. The report contains pertinent information supporting the code change.

Measure Description

Background Information

Drain water heat recovery (DWHR) is a technology used to conserve energy for water heating. The technology utilizes a heat exchanger to transfer heat from warm drain water to cold supply water. Drain water heat exchangers can recover heat from a variety of sources, including showers, bathtubs, sinks, dishwashers, clothes washers, and industrial processes.

DWHR technology has been available since 1986, and was introduced into Title 24, Part 6 for residential applications for the 2019 code cycle (Statewide CASE Team n.d.). In the 2019 Title 24, Part 6 requirements, DWHR is part of an alternative prescriptive pathway for single family and low-rise multifamily buildings. The alternative prescriptive pathway allows gas storage water heaters and heat pump water heaters to be installed in combination with other efficiency measures including DWHR (Section 150.1(c)8A). HERS-verified DWHR is also one option for achieving CALGreen Tier 2. DWHR is currently available as a compliance option for all residential buildings and for High-Rise Residential Living Spaces within nonresidential buildings. Prior to adopting DWHR requirements for 2019 Title 24, Part 6, energy savings from shower DWHR in North America were demonstrated in the Provinces of Ontario and Manitoba, Canada, where shower DWHR is a requirement for prescriptive compliance with the residential energy code.

A separate, concurrent 2022 code change proposal by the Statewide CASE Team attempted to make shower DWHR a primary prescriptive requirement for all multifamily buildings. The multifamily DWHR measure was found to be not cost effective due to the submetering requirements included in Senate Bill 7 (SB 7, Wolk 2016), which requires independent submetering of all domestic water entering residential dwelling units. The submetering requirements of SB 7 apply to residential buildings only and would not affect DWHR installed in nonresidential buildings.

Proposed Code Change

The proposed code change introduces a new compliance option for shower DWHR in hotels, motels, dormitories, senior living facilities, and other buildings with shower facilities. The proposed change does not impact additions or alterations. The proposed code change also entails clarifying Section 110.3 to include DWHR as recovered energy that can be used to meet the service water heater requirements in state buildings.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, and compliance documents would be modified as a result of the proposed change(s).

Table 1: Scope of Code Change Proposal

Measure Name	Type of Require ment	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Nonresidential Drain Water Heat Recovery	Complia nce Option	100.1(b), 110.3	2.1.1 Manufacturer Certification of Equipment, Produces, and Devices	Yes – 5.9.1.4 Water Heating Auxiliaries	NRCC-PRF-01-E

Market Analysis and Regulatory Assessment

DWHR manufacturing in North America consists of four companies located in Canada. Despite no United States (U.S.) manufacturing presence, DWHR devices are available to U.S. customers through regional distributors and retail plumbing supply stores. All manufacturers interviewed by the Statewide CASE Team confirmed that current import/export tariffs in 2019 were insignificant and do not pose a barrier to U.S. customers.

Effectiveness of vertical DWHR units sold in California are rated according to the Canadian Standards Association (CSA) performance standard (CSA 2015a) and safety standard (CSA 2015b). Similarly, effectiveness of horizontal DWHR units sold in California are rated according to the International Association of Plumbing and Mechanical Officials (IAPMO) performance standard (IAPMO 2017) and safety standard (IAPMO 2013).

Vertical and horizontal drain water heat exchangers are addressed by Appendix L Section 606 of the California Plumbing Code (CPC), which requires DWHR to be compliant with IAPMO PS 92 and be accessible. The proposed code language does not address DWHR accessibility, because accessibility is already addressed in the CPC.

There are no relevant local, state, or federal laws related to nonresidential DWHR systems. DWHR technology is promoted and encouraged only as a voluntary energy-saving measure by the U.S. Environmental Protection Agency (EPA) ENERGY STAR® program in Canada and is promoted by the U.S. Department of Energy (DOE). Therefore, there are no mandatory federal regulatory requirements that California policymakers need to consider.

Cost Effectiveness

The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-Year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The higher the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio for this measure is between 0.35 and 0.72 depending on climate zone. Thus, shower DWHR was not found to be cost effective for any prototype building in any climate zone and the Statewide CASE Team is not recommending adding DWHR as a mandatory requirement or requirement for the primary prescriptive path. See Section 5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts

No statewide savings or GHG emissions impacts can be claimed for proposed changes to compliance options in the performance path. However, the Statewide CASE Team has calculated the potential statewide savings that would be realized if a DWHR prescriptive requirement were adopted. See Section 6 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 4 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 2: First-Year Statewide Energy Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (MMTherms/yr)	TDV Energy Savings (TDV kBtu/yr)
New Construction	0	0	0	0
Additions and Alterations	0	0	0	0

Table 3: First-Year Statewide GHG Emissions Impacts

Measure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Nonresidential DWHR	0	$0
Total	0	$0

Water and Water Quality Impacts

The proposed measure is not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Section 2.5. Impacts that the proposed measure would have on market actors is described in Section 3.3 and Appendix E. The key issues related to compliance and enforcement are summarized below:

- DWHR devices are installed on shower drain lines and require consideration during piping layout design. Configuration and layout affect energy savings and could affect the layout of the walls and other utilities within them.
- Installation of DWHR requires approximately two additional labor hours per unit and requires coordination with the framing and insulation contractors.
- DWHR units may require additional inspection and/or require a Certificate of Installation and/or Verification.
- The California Plumbing Codes (CPC) requires DWHR devices to be accessible.

Field Verification and Acceptance Testing

DWHR device manufacturers would self-certify their products via laboratory testing to evaluate rated effectiveness under either the CSA (CSA 2015a) or IAPMO (IAPMO 2017) performance standards. Design engineers would be required to list rated effectiveness on the compliance documents. Plans examiners would check that the rated effectiveness listed on the compliance documents matches the design drawings.

1. Introduction

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The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison– and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this Final CASE Report is to present a code change proposal for nonresidential drain water heat recovery (DWHR). The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on October 3, 2019 (Statewide CASE Team n.d.) and was developed in coordination with the Multifamily DWHR proposal (Feng 2020).

The following is a brief summary of the contents of this report:

- Section 2 – Measure Description of this Final CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.

- Section 3 – In addition to the Market Analysis section, this section includes a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 4 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 5 –This section includes a discussion and presents analysis of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 6 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic in by the state of California. Statewide water consumption impacts are also reported in this section.
- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with strikeout (deletions) and underlined (additions) language for the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, Compliance Manual, and compliance documents.
- Section 8 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in

water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

- Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software.
- Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Energy Cost Savings Using Nominal Dollars presents energy cost savings over the 15-Year period of analysis in nominal dollars.

2. Measure Description

2.1 Measure Overview

The proposed code change introduces a new compliance option for shower DWHR in hotels, motels, dormitories, senior living facilities and other nonresidential buildings with shower facilities. Compliance credit can be achieved by installing DWHR devices on shower facilities in nonresidential buildings, provided that the devices have a minimum rated effectiveness of 42 percent and are compliant with either Canadian Standards Association (CSA) B55.1 or the International Association of Plumbing and Mechanical Officials (IAPMO) IGC 346-2017. The proposed change does not impact additions or alterations. The proposed code change also clarifies Section 110.3(c)5 of the standards by including DWHR as a form of recovered energy that can be counted towards the solar and energy recovery requirements for service water heating systems in state buildings.

The proposed code change requires modifications to the NRCC-PLB-01-E compliance document as described in Section 7.4.

The proposed code change requires modifications to the nonresidential compliance software (CBECC-Com) as detailed in Appendix D.

2.2 Measure History

DWHR is a technology used to conserve energy for water heating. The technology utilizes a heat exchanger to transfer heat from warm drain water to cold supply water. Drain water heat exchangers can recover heat from a variety of sources, including showers, bathtubs, sinks, dishwashers, clothes washers, and industrial processes.

DWHR technology has been available since 1986, and it was introduced in Title 24, Part 6 by the 2019 Statewide CASE Team (Statewide CASE Team n.d.). In the 2019 Title 24, Part 6 requirements, DWHR is part of an alternative prescriptive pathway for single family and low-rise multifamily buildings that allows gas storage water heaters or heat pump water heaters to be installed in combination with other efficiency measures including DWHR (Section 150.1(c)8A). HERS-verified DWHR is also one option for achieving CALGreen Tier 2. DWHR is currently available as a compliance option for all residential buildings and for high-rise residential living spaces within nonresidential buildings. Prior to adopting DWHR requirements for 2019 Title 24, Part 6, energy savings from shower DWHR in North America were demonstrated in the Canadian provinces of Ontario and Manitoba where shower DWHR is a requirement for prescriptive compliance with the residential energy code.

DWHR is implemented in a variety of configurations depending on the application. The pre-heated water can be routed to a storage tank, fixture, and/or appliance. Systems that route pre-heated water to both a storage tank and a fixture or appliance are described as “equal flow” configurations (Figure 1). “Unequal flow” configurations route pre-heated water to either a storage tank (Figure 2), a fixture, or an appliance (Figure 3). DWHR devices can be installed in vertical, horizontal, and sloped arrangements. DWHR designs are typically passive systems and require little to no maintenance. However, some systems, especially in sloped or horizontal configurations, can incorporate pumps and controllers and may require regular cleaning to maintain effectiveness. Some industrial applications use DWHR for tempering drain water, to comply with drain temperature regulations (e.g., International Plumbing Code prohibits drain water temperatures above 140°F from entering sewer systems). This proposal does not cover DWHR used for water tempering because these systems are used exclusively for process applications where the primary benefit is conserving water rather than energy.

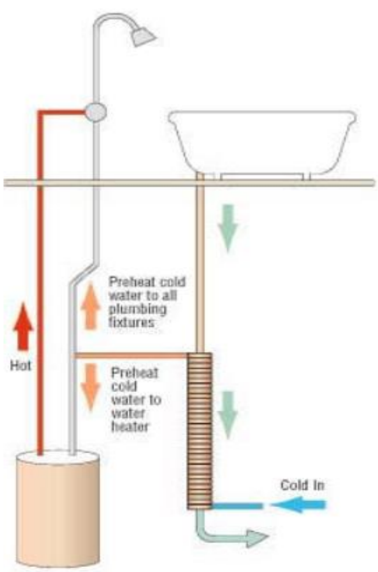

Figure 1: Equal flow.

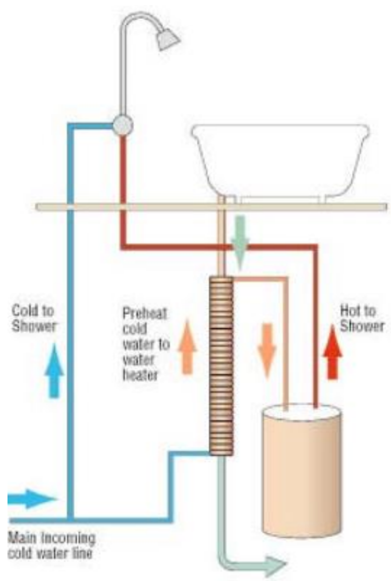

Figure 2: Unequal flow to tank.

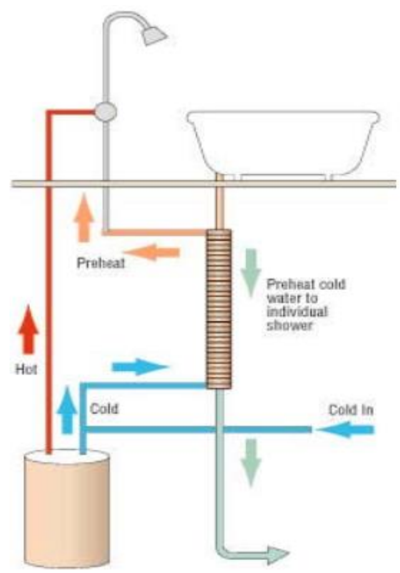

Figure 3: Unequal flow to fixture.

Source: http://gfxtechnology.com/Install-Page.pdf

This proposal introduces a new compliance option for shower DWHR in hotels, motels, dormitories, senior living facilities, and other nonresidential buildings with shower facilities. The 2022 Statewide CASE Team originally pursued a prescriptive requirement for DWHR in nonresidential buildings but concluded that it was not cost effective. Expanding the space types which can utilize DWHR as a compliance option would allow for including DWHR as part of an alternative prescriptive package for nonresidential buildings, similar to the existing alternative prescriptive pathway for domestic hot water (DHW) in single family and low-rise multifamily buildings.

Industry specifications for testing, performance, labeling, and safety of DWHR units are established and referenced by building code requirements in California and elsewhere. These specifications are discussed further in Section 2.4.4.

The 2019 Statewide CASE Team tested multiple DWHR products in laboratories to develop algorithms for estimating energy savings in residential buildings. The software development teams for the California Simulation Engine (CSE) and California Building Energy Code Compliance (CBECC) incorporated these algorithms into the 2019 residential compliance modeling software (CBECC-Res 2019). Shower DWHR is currently supported in the nonresidential compliance modeling software (CBECC-Com 2019) as a compliance option for domestic water heating systems that serve High-Rise Residential Living Spaces. The 2022 Statewide CASE Team has outlined new specifications for updating the CBECC-Com software to support DWHR for systems serving other residential space functions as part of this proposal. The software specification is included in Appendix D of this report.

2.3 Summary of Proposed Changes to Code Documents

The sections below summarize the necessary modifications to the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents to support the proposed code change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

— **SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION:** Add a definition of DWHR to help clarify code requirements for all building types.

— **SECTION 110.3 – MANDATORY REQUIRMENTS FOR SERIVCE WATER-HEATING SYSTEMS AND EQUIPMENT:** Clarify that energy recovered from DWHR units counts towards the recovered energy requirements for water heating systems in state buildings.

2.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below. See Section 7.3 of this report for the detailed proposed revisions to the text of the reference appendices.

- **Section 2.1.1 Manufacturer Certification for Equipment, Products, and Devices:** Add DWHR as a type of equipment that manufacturers would need to self-certify to the Energy Commission.

2.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify Section 5 – Building Descriptors and References of the Nonresidential ACM Reference Manual. The proposal would include DWHR in the Water Heating System Configuration definition and add a definition for DWHR effectiveness. See Section 7.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

2.3.4 Summary of Changes to the Nonresidential Compliance Manual

This proposal would not require changes to the Nonresidential Compliance manual.

2.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify NRCC-PRF-01-E. The proposed regulations add a table for DWHR specifications and configuration onto this document. This would help ensure that the installation matches the energy model and that the system saves the expected amount of energy.

Examples of the revised documents are presented in Section 7.6.

2.4 Regulatory Context

2.4.1 Existing Requirements in the California Energy Code

Existing DWHR requirements in Title 24, Part 6 apply only to residential buildings. Gas or propane domestic water-heating systems serving individual dwelling units are required to include either a compact hot water distribution system or a DWHR system (Section 150.1(c)8Aii). Heat pump water heaters serving individual dwelling units are required to include either a compact hot water distribution with DWHR or a solar photovoltaic system with capacity requirements based on climate zone (Section 150.1(c)8Aiv). Central water-heating systems in residential buildings are required to include a solar water-heating system, and solar fraction requirements are reduced if a DWHR system is installed (Section 150.1(c)8Biii).

There are currently no existing code requirements for DWHR in nonresidential buildings. However, there are some notable overlaps between residential and nonresidential compliance modeling regarding Domestic Hot Water (DHW) and DWHR. Multifamily buildings that are four or more stories are subject to nonresidential efficiency standards, even though the spaces within the building are classified as residential. Similarly, hotels/motels are subject to nonresidential efficiency standards, but hotel/motel guest rooms are classified as residential spaces. Regardless of which efficiency standards apply to the building, all DHW systems serving residential spaces that are pursuing performance-based compliance are simulated in CSE, both in CBECC-Res and CBECC-Com. There are currently only two residential space functions in CBECC-Com: Hotel/Motel Guest Room and High-Rise Residential Living Spaces. As mentioned previously, DWHR is already a compliance option in CBECC-Com for High-Rise Residential Living Spaces. Therefore, adding a compliance option for shower DWHR in CBECC-Com for all residential space functions simply entails allowing DWHR systems to serve Hotel/Motel Guest Rooms and any future residential space functions included in CBECC-Com.

Effectiveness of vertical DWHR units sold in California are rated according to the CSA performance standard (CSA 2015a) and safety standard (CSA 2015b). Similarly, effectiveness of horizontal DWHR units sold in California are rated according to the IAPMO performance standard (IAPMO 2017) and safety standard (IAPMO 2013). The CSA standards are adopted by reference in the International Code Council's (ICC) International Energy Conservation Code (IECC, Chapter Four), International Residential Code (Chapter 11), and the 2015 International Green Construction Code (Chapter Six).

Vertical and horizontal drain water heat exchangers are addressed by Appendix L Section 606 of the California Plumbing Code (CPC or Title 24, Part 5), which requires DWHR to be compliant with IAPMO PS 92 and be accessible. The proposed code language does not address DWHR accessibility because accessibility is already addressed in the CPC.

2.4.2 Relationship to Requirements in Other Parts of the California Building Code

Greywater is wastewater generated in households or office buildings from water streams that do not contain fecal contamination. Sources of greywater include sinks, showers, bathtubs, and clothes washing machines. The California Plumbing Code (Title 24, Part 5) sets the regulatory standards for plumbing and installations of greywater systems. The California Water Code (Section 14877) defines a greywater system as, "…a system and devices, attached to the plumbing system for the sanitary distribution or use of greywater." Due to the increasing importance of greywater systems as a tool within the state's portfolio of water conservation programs, and the potential for DWHR units to be complementary or a part of greywater systems, California policymakers need to ensure that future Title 24, Part 5 plumbing standards are coordinated closely with any new DWHR requirements in the 2022 Title 24, Part 6 Standards.

2.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws related to nonresidential DWHR systems. DWHR technology is promoted and encouraged only as a voluntary energy-saving measure by the United States (U.S.) Environmental Protection Agency (EPA) ENERGY STAR® program in Canada and is promoted by the U.S. Department of Energy (DOE). Therefore, there are no mandatory federal regulatory requirements that California policymakers need to consider, nor are any new requirements likely in the near future at the federal level

2.4.4 Relationship to Industry Standards

CSA has both a performance standard (CSA 2015a) and a safety standard (CSA 2015b) for DWHR units that together serve as the current industry standard. All DWHR manufacturers adhere to these CSA industry standards as referenced in national and international building codes. The proposed code language in this Final CASE Report incorporates the CSA standards by reference and proposes no changes to existing standards. Similarly, IAPMO has a performance standard for horizontal units (IAPMO 2017) and a safety standard for horizontal and vertical units (IAPMO 2013).

Two applicable standards have been published for vertical DWHR devices by CSA to address DWHR testing, performance, labeling, and safety: CSA B55.1 (CSA 2015a) and CSA B55.2 (CSA 2015b). These CSA standards are referenced in IECC 2015 and the residential building energy codes of Manitoba and Ontario, Canada. In each of these energy codes, DWHR units are required to undergo testing and labeling in accordance with the CSA.

The IAPMO IGC 346 addresses horizontal DWHR testing, performance, and labeling (IAPMO 2017). IAPMO PS 92 addresses DWHR safety (IAPMO 2013) for both horizontal and vertical DWHR devices.

2.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Equipment Certification:** Manufacturers must certify DWHR units to the Energy Commission, confirming that each unit meets the code requirements for safety and efficiency. Specifically, manufacturers must certify that the DWHR units have a minimum rated effectiveness of 42 percent. Vertical units must be compliant with CSA B55.2 and be tested and labeled in accordance with CTA B55.1 or IAPMO IGC 346-2017. Sloped units must be compliant with IAPMO PS 92 and be tested and labeled with IAPMO 346-2017.

- **Design Phase:** DWHR is considered by plumbing engineers during the design of the DHW distribution system and water heating load calculations. DWHR units are shown on the plumbing design drawings, indicating their placement on the drain line in the piping layout and configuration details (i.e., vertical or sloped configuration, equal or unequal flow). Designers should also specify the DWHR unit manufacturer, model, and rated effectiveness on the plumbing equipment schedule.
- **Permit Application Phase:** Performance specifications listed on the compliance modeling output report are verified by the plans examiner by referencing the plumbing equipment schedule.
- **Construction Phase:** DWHR installation is performed by a licensed plumber and typically takes less than two additional hours of labor per unit (Statewide CASE Team n.d.). Installation requires coordination with framing and insulation contractors.
- **Inspection Phase:** The plumbing contractor would complete the appropriate Certificate of Installation (NRCI) and included it with the construction documents. Acceptance tests are not required.

Including DWHR as a compliance option does not present any significant changes to the compliance verification process. The compliance modeling software (CBECC-Com) would include a table on the output report if a DWHR device is included in the proposed building design. The plans examiners would need to verify that the performance characteristics and configuration listed on the compliance report matches those listed on the plumbing equipment schedule. The plumbing contractor should install DWHR units only in the configuration for which they are rated to ensure performance is consistent with the rating. Once the device is installed, the plumbing contractor would complete the appropriate Certificate of Installation (NRCI) form and include it with the construction documents. Acceptance testing is not anticipated because the devices are already self-certified by the manufacturer to perform at a rated effectiveness, and energy credits provided via compliance simulation are based on the unit's rated effectiveness.

3. Market Analysis

3.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on October 3, 2019 (Statewide CASE Team 2019).

The typical distribution channels for DWHR devices include six primary market actors: manufacturers, regional distributors, wholesale and retail plumbing equipment suppliers, plumbing engineers and contractors. DWHR units are sold to plumbing contractors either during the construction of a new piping distribution system or as an alteration to an existing system. DWHR manufacturing in North America consists of six companies located in Canada (Ecodrain, EcoInnovation, RenewABILITY Energy Inc., ReTHERM Energy Systems, Watercycles, and Sharc International) and one manufacturer located in Colorado (Swing Green). All manufacturers produce vertical DWHR devices, and Ecodrain also produces devices designed and rated specifically for horizontal configurations. One manufacturer estimated approximately 20,000 DWHR units sold in 2015, and a total of 100,000 DWHR units in operation in North America, the vast majority of which are in Canada. The DWHR manufacturing industry is relatively small, with most companies employing less than five full-time equivalent (FTE) employees.

Most DWHR devices are warrantied between four and ten years, with an expected useful life ranging from 30 to 50 years, based on interviews with manufacturers. Vertical DWHR units, which account for roughly 95 percent of the market, require no maintenance or moving parts. Horizontal or sloped DWHR units account for the remaining 5 percent of the market and, while they also require no moving parts, they do require occasional cleaning to remove grease and other debris that could build up over time and reduce the unit’s effectiveness. Although units designed for vertical configurations can be installed in sloped or horizontal configurations, albeit at reduced effectiveness, there is currently only one manufacturer (Ecodrain) producing devices specifically designed and rated for horizontal configurations. Horizontal DWHR devices accommodate space limitations associated with single-story and ground-level applications. Ecodrain supported the establishment of the IAPMO IGC 346 test protocol for certifying effectiveness of horizontal DWHR units, which was largely based on the previously established CSA B55.1 test protocol for certifying vertical units.

3.2 Technical Feasibility, Market Availability, and Current Practices

3.2.1 Technical Feasibility

DWHR in nonresidential buildings typically involves more than one heat exchanger and/or shower. In these cases, systems are classified as either distributed or central/ganged systems, depending on the location of the DWHR devices. Distributed system designs have DWHR units installed on the shower drain stacks, typically in risers or between walls throughout the building. Central/ganged systems have DWHR units installed in parallel at a central location and can be used to capture heat from sources other than just showers.

Distributed DWHR Systems

Buildings utilizing DWHR across multiple floors typically have distributed systems with DWHR units shared between multiple showers. Such systems are typically configured for unequal flow to the shower fixtures, where one DWHR unit captures drain water from multiple showers and preheats cold water supplied to the same showers. Multiple DWHR units can be installed in a drain stack but should be separated by pressure zone to eliminate the need for a booster pump on the preheated water. Configurations where pre-heated water is routed to the water heater are not common in multi-story distributed systems, due to the added piping costs.

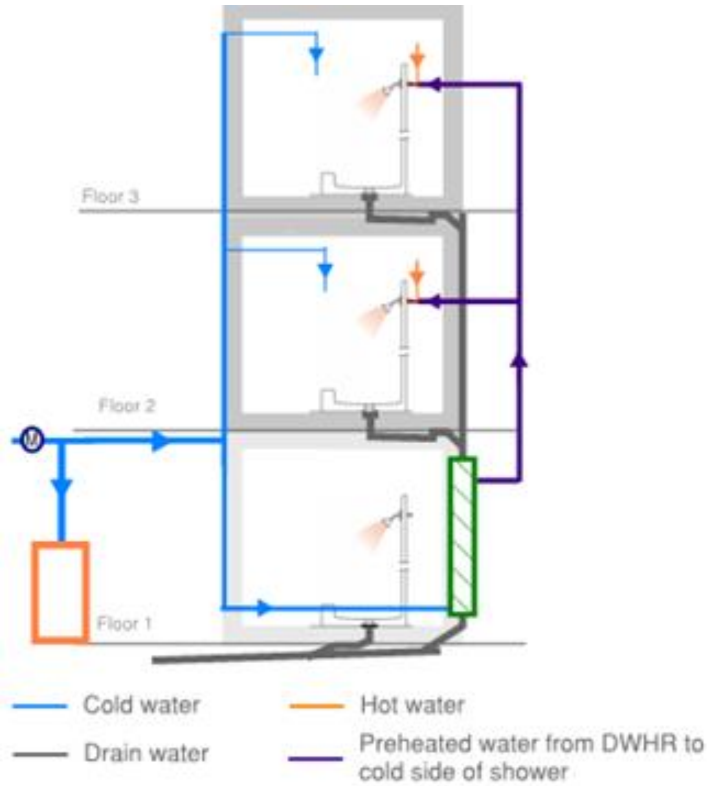

Figure 4: Distributed DWHR system schematic with one DWHR serving two shower fixtures (unequal flow to the shower fixture).

Source: (Feng 2020)

Central/ Ganged DWHR Systems

Central/ganged DWHR systems typically serve multiple vertical drainage stacks that feed into either a single DWHR device or a manifold of multiple devices. The DWHR unit is typically located in a ground floor mechanical room as illustrated in Figure 5. Central systems are typically designed for unequal flow to the water heater configurations because the DWHR units are typically installed close to the water heater.

Individual drainage stacks are often distributed throughout the building footprint, and therefore the routing between the base of the individual drain stacks and the DWHR device/manifold can be long. The UPC Section 708.0 requires that horizontal drainage piping shall have a minimum slope of 0.25 inches per linear foot (IAPMO 2019). Drainage stacks are typically not located close enough together to allow all stacks to feed into a central DWHR device/manifold. Therefore, centralized DWHR systems can only be achieved in certain scenarios that are carefully considered during the plumbing design.

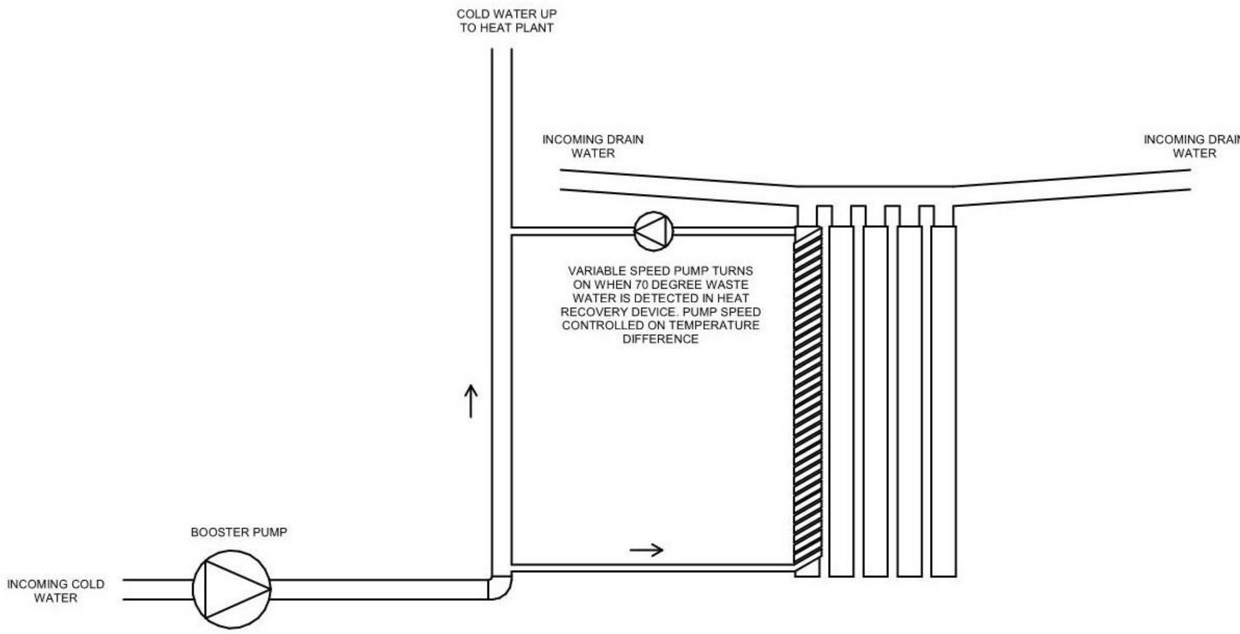

Figure 5: Central DWHR plant schematic

Source: (Feng 2020)

Including DWHR into a new construction domestic water distribution system requires minimal training for builders and plumbing designers and is not expected to cause significant delays in construction. Early consideration of DWHR during the design phase would help optimize energy savings and system losses. Training is recommended for inspecting DWHR units before chases of walls are enclosed or otherwise made inaccessible.

DWHR units are constructed almost entirely from copper and have expected useful lifetimes much longer than associated DHW equipment and appliances. Manufacturers estimate expected useful life of DWHR units from 30 to 50 years.

Horizontal or sloped DWHR configurations should also be supported as a compliance option, provided the units are rated according to the IAPMO IGC 346 test procedure, which was specifically developed for rating sloped DWHR devices. Some DWHR systems use devices that are intended for vertical installation but are installed on a sloped angle to accommodate space limitations. A vertical DWHR device can still provide substantial heat recovery in a sloped configuration, albeit at reduced effectiveness. Since vertical DWHR devices are rated according to CSA test procedures, which require a vertical configuration, the CSA-rated effectiveness would not be accurate for the same device installed in a sloped configuration. Instead, the device would be required to be tested according to the IAPMO IGC 346 test procedure. In the absence of an IAPMO rated effectiveness, a generic algorithm can be used to predict the performance of vertical DWHR devices installed in sloped configurations

(Grant et al, 2019). CBECC-Com could utilize this algorithm to estimate effectiveness of sloped DWHR devices by requiring slope angle as an additional input.

The Statewide CASE Team identified the following potential challenges to a successful DWHR project:

- Appendix L of the California Plumbing Code requires DWHR units to be accessible and compliant with IAPMO PS 92 (CPC Appendix L 506.1). Per CPC 1.1.4, CPC appendices are optional unless adopted by a state agency or local enforcing agency. Per the “Matrix Adoption Table” for Appendix L, no state agencies have adopted any section of Appendix L. However, local enforcing agencies may choose to adopt Appendix L. If a local enforcing agency adopts Appendix L, it would require DWHR devices to be accessible and compliant with IAPMO PS 92.
- Reduced energy savings could result if design and construction teams do not coordinate the drain piping layout, DWHR configuration, and performance specifications. DWHR installations must match the make, model, rated effectiveness, and configuration listed on the compliance output report (NRCC-PRF-01) in order to achieve the energy savings calculated by the model.

3.2.2 Market Availability

Despite limited U.S. manufacturing presence, DWHR devices are readily available to U.S. customers through regional distributors and retail plumbing supply stores. All manufacturers interviewed by the Statewide CASE Team confirmed that current Canadian import/export tariffs in 2019 were insignificant and do not pose a barrier to U.S. customers. Current manufacturing capacity is adequate for meeting any increase in demand resulting from new regulations mandating or encouraging DWHR in California or elsewhere in the U.S., according to interviews with four manufacturers.

3.2.3 Current Practices

DWHR technology has been implemented sparsely in the United States but has significantly more installations in Canada due to the provincial energy code requirements. DWHR was adopted in 2016 as mandatory and prescriptive requirements for new construction residential buildings in the Canadian providences of Manitoba and Ontario, respectively. Both provincial building energy codes establish a minimum DWHR unit efficiency of 42 percent and require DWHR units for each shower, but not more than two per residence.

DWHR was also adopted in the 2019 California Residential Efficiency Standards as an alternative prescriptive pathway for single family and low-rise residential buildings. Numerous case studies and laboratory testing obtained from manufacturers demonstrate cost-effectiveness of shower DWHR, with simple paybacks ranging between three to five years, depending on the usage profile, rated effectiveness, and watermain temperatures. The Statewide CASE Team identified several DWHR installations in dormitories and hotels in California. However, DWHR is not widespread in California due to the limited market penetration and skepticism over whether the technology is cost-effective in mild climates.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 4).[1] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 4: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9

[1] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed compliance option would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 5 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The proposed code change is not expected to significantly impact builders. The only potential impact on builders would be a marginal increase in building costs associated with installing DWHR in buildings where four or more showers share a drain line, which is not expected to impact profits from constructing buildings. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.4 Economic Impacts.

Table 5: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.5

Source: (State of California, Employment Development Department n.d.)

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 6 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for nonresidential DWHR to marginally affect firms that focus on hotel, dormitory, and senior living construction.

There is not a North American Industry Classification System (NAICS)[2] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[3] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 6 provides an upper bound indication of the size of this sector in California.

Table 6: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.91
Building Inspection Services [b]	824	3,145	$0.22

[2] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[3] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

The proposed code change does not require any changes to building design or energy analysis. However, if this compliance option is adopted, it would provide an option for building designers to achieve energy credit for including DWHR in the plumbing design. If DWHR is included in the plumbing design, energy consultants would need to include DWHR in the performance energy model. It would be important for building designers to effectively communicate and coordinate with plumbing contractors and energy modelers about DWHR efficiency and installation requirements.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants, or those involved with the construction, commissioning, and maintenance of the building.

The proposed changes to the DWHR compliance options would not be available for healthcare facilities.

3.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

The primary benefit of DWHR for building owners is reduced energy costs for water heating. The primary deficit to building owners and developers are the additional design, material, and construction costs associated with installing DWHR.

The proposed measure would have minimal to no impact on building maintenance. On-demand shower DWHR is a passive technology which requires no maintenance for vertical configurations. Horizontal DWHR configurations may require infrequent cleanings to maintain original effectiveness and prevent clogging.

The technology makes no noise and would not be seen when enclosed in an interior wall or shaft and if exposed, it would typically be in a mechanical room or basement. However, if accessibility and inspection are required by local regulations, the additional costs associated with these requirements may be significant enough to prevent acceptance.

3.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

Adoption of the proposed measure may impact manufacturers, distributors, and retailers by increasing the demand for DWHR products. Manufacturers have verbally confirmed their ability, and the ability of associated distributors and retailers, to meet any potential increase in demand resulting from the adoption of this measure.

3.3.6 Impact on Building Inspectors

Inspection of DWHR units is a simple task since they are installed as part of the domestic water distribution system during the early stages of construction. DWHR units in high-rise buildings are often installed in risers or behind walls, which may inhibit accessibility. Training for inspection agents is recommended, but due to the simplicity of the technology and its installation, the required time is expected to be minimal.

Table 7 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 7: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6.

The proposed measure may have some minimal impacts on employment in the state, which is likely to be limited to plumbing retailers and contractors. The technology requires minimal training due to the simple product design and installation procedures. Furthermore, were a DWHR manufacturer to locate in California, manufacturing job creation is expected to be minimal. Each of the four Canadian DWHR manufacturers interviewed by the Statewide CASE Team stated they had no more than five FTEs on staff.

3.4 Economic Impacts

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed code change would result in additional spending by those businesses.

3.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.4 would lead to modest changes in employment of existing jobs.

3.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to the plumbing layout, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses operating incorporated in California, regardless of whether the business is located inside or outside of the state. Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[4] As Table 8 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 8: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.245	1,740.349	35%

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[4] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2016	455.980	1,739.838	26%
2017	509.276	1,813.552	28%
2018	618.247	1,843.713	34%
2019	580.849	1,826.971	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 13 through Table 17 above by 31 percent.

3.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

The Statewide CASE Team does not expect the proposed code changes would have a measurable impact on the California's General Fund, any state special funds, or local government funds.

3.4.6 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population including migrant workers, commuters, or persons by age, race, or religion.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors presented during the Energy Commission's March 27, 2020 workshop on compliance metrics. (California Energy Commission 2020) The electricity TDV factors include the 15 percent retail adder and the natural gas TDV factors include the impact of methane leakage on the building site. The electricity TDV factors used in the energy savings analyses were obtained from Energy and Environmental Economics, Inc. (E3), the contractor that is developing the 2022 TDV factors for the Energy Commission, in a spreadsheet titled "Electric TDVs 2022 - 15 pct Retail Adj Scaled by Avoided Costs.xlsx". The natural gas TDV factors used in the energy savings analyses were obtained from E3 in a spreadsheet titled "2022_TDV_Policy_Compliant_CH4Leak_FlatRtlAdd_20191210.xlsx". The electricity demand factors used in the energy savings analysis were obtained from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values would increase the TDV factors slightly. As a result, the TDV energy savings presented in this report are lower than the values that are expected if the final TDV use 20-year GWP values, and the proposed code changes will be more cost effective using the revised TDV. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

The 2019 Statewide CASE Team tested multiple DWHR products in the lab to develop an algorithm for estimating DWHR energy savings in residential buildings. The algorithm developed from the lab testing was used by the 2019 Statewide CASE Team to estimate energy savings for DWHR in single family and low-rise multifamily buildings (Statewide CASE Team 2019) and is now incorporated into CSE and, by extension, CBECC-Res and CBECC-Com. The energy savings calculations performed in support of this proposal are simulated in CSE and utilized the same algorithm to estimate shower DWHR savings in nonresidential buildings.

Energy savings are simulated using the ApartmentHighRise and HotelSmall prototype energy models in CBECC-Com. The ApartmentHighRise and HotelSmall prototypes are nonresidential buildings that contain residential living spaces (high-rise residential living spaces/dormatoriesHigh-Rise Residential Living Spaces and Hotel/Motel Guest Rooms, respectively). CBECC-Com utilizes CSE to simulate DHW in residential living spaces, which uses the hot water draw profiles developed for CBECC-Res (Kruis, et al. 2017). The hot water draw profiles incorporate separate hot water end use profiles for faucets, showers, baths, clothes washing, and dishwashers. The models assume drain water from all showers, baths, and faucets in each residential living space flow through a single DWHR unit (one unit per residence). Supply water temperatures in each climate zone are assumed based on the watermain temperature schedules assigned by CBECC-Com. The preheated cold water is supplied to the shower fixture (i.e., unequal flow to the shower), as this is the most common configuration likely to be installed in multi-story hotels and dormitories. Although typical design in multi-story buildings combine drain water from up to four residences on a single DWHR device, this capability is not yet supported in CSE. The cost-saving implications of sharing DWHR devices between multiple residential units is accounted for in the incremental first-cost estimates, however, energy savings are estimated assuming each residential unit has its own DWHR device. The distance between the drain and heat exchanger is not accounted for, but this distance is minimal for the assumed configuration.

The DWHR units are assumed to be 48-inch long by 4-inch diameter drainpipes with ¾-inch supply water lines, as these are the most common dimensions for commercial DWHR applications. The DWHR effectiveness was assumed to be 42 percent, which is the minimum allowed in residential buildings. The DHW systems serving the residential spaces in each prototype model have the same Standard Design: central, gas-fired water heater, 80 percent thermal efficiency, 250 kBtuh capacity with 100-gallon storage.

The key assumptions can be summarized as follows:

- ApartmentHighRise and HotelSmall prototype models simulated in CBECC-Com/CSE.
- One DWHR device per residential living space (i.e., hotel/motel guest rooms and high-rise residential living spaces).
- 42 percent rated effectiveness (minimum allowed in California residential buildings).
- Heat recovered from showers, baths, and faucets supplied to showers (i.e., unequal flow to the shower).
- Standard Design DWH system: central, gas-fired water heater, 80 percent thermal efficiency, 250 kBtuh capacity, 100-gallon storage.

4.2 Energy Savings Methodology

4.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries and space functions for different types of buildings (California Energy

Commission 2019). The only nonresidential building types forecasted by the Energy Commission that have showers are Colleges and Hotel/Motels (Table 11). The Hotel/Motel building type is represented entirely by the HotelSmall prototype energy model. Colleges are represented by a composite of six prototype energy models, but only the ApartmentHighRise model has showers. In this case, the ApartmentHighRise prototype model is intended to represent a dormitory building, rather than an actual apartment building. The analysis utilizes these two CBECC-Com prototype models (i.e., ApartmentHighRise and HotelSmall) to simulate the impact of installing DWHR devices on all shower, bath, and faucet drains, routing the pre-heated supply water to the shower fixtures (i.e., unequal flow to fixture).

The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 9. Statewide savings were estimated for only New Construction floor area forecasts for the building types comprised of the prototypes listed below.

Table 9: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
ApartmentHighRise	10	93,632	10-story apartment building with a basement and elevator penthouse, 75 residential units and other common spaces including lobby, office, multipurpose room, exercise center, laundry, and storage.
HotelSmall	4	42,554	4-story Hotel with 77 guest rooms. WWR-11%

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for nonresidential buildings (California Energy Commission 2020a). The ApartmentHighRise and HotelSmall prototype models, summarized in Table 9, were simulated in CBECC-Com for each climate zone. When CBECC-Com simulates a model, it first generates the baseline and proposed input files for the appropriate simulation engine(s). For buildings that have residential DHW systems, such as the ApartmentHighRise and HotelSmall prototypes, CBECC-Com produces baseline and proposed input files for both CSE (which is used to simulate only the DHW system) and EnergyPlus (which is used to simulate all other components of the model).

The baseline CSE input files generated by CBECC-Com for ApartmentHighRise and HotelSmall were modified using a text editor to apply DWHR for each shower in the model. The modified CSE input files were then simulated in CSE directly via command line using the CSE executable program installed as part of the CBECC-Com software package. The unmodified baseline input files generated by CBECC-Com serve as the baselines for each building type. The Standard Design DHW systems for the ApartmentHighRise and HotelSmall prototypes are the same: central gas-fired storage water heater (100 gallons, 250 kBtuh, 80 percent thermal efficiency). Details regarding the Standard Design are described in the 2019 Nonresidential ACM Reference Manual. The proposed design reflects minimum-allowable rated effectiveness (42 percent) for DWHR devices with unequal flow to the shower fixture. Table 10 presents precisely which parameters were changed in the Standard Design models to reflect DWHR in the Proposed Design.

Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements.

Table 10: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Names	Standard Design Parameter Value	Proposed Design Parameter Value
ApartmentHigh Rise & HotelSmall	All	DHWHEAT REC	wrType	Blank	Vertical
" "	" "	" "	wrCountFXDrain	" "	1
" "	" "	" "	wrCountFXCold	" "	1
" "	" "	" "	wrFeedsWH	" "	No
" "	" "	" "	wrCSARatedEF	" "	0.42

The energy impacts of shower DWHR vary by climate zone, due to differing watermain temperatures. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the appropriate TDV factors when calculating TDV energy cost impacts.

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building are translated into impacts per square foot by dividing by the floor area of the prototype building. This allows for easier comparison of savings across different building types and enables calculation of statewide savings using the published construction forecast in terms of floor area by building type.

4.2.2 Statewide Energy Savings Methodology

The Statewide CASE Team estimated energy cost savings and implementation costs to establish whether nonresidential shower DWHR is cost effective in nonresidential buildings. The Statewide CASE Team found that nonresidential shower DWHR is not cost effective and changed this proposal to reflect a compliance option instead of a prescriptive requirement. Therefore, the energy budget would not be impacted and there would be no claimable statewide savings associated with the proposed performance path compliance option revisions.

The per-unit energy impacts presented in this section represent the savings that could result from DWHR installed in nonresidential buildings. The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided. The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The building types used in the construction forecast, Building Type ID, are not identical to the prototypical building types available in CBECC-Com, so the Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 11 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

Table 11: Nonresidential Building Types and Associated Prototype Weighting

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Small Office	OfficeSmall	100%
Large Office	OfficeMedium	50%
" "	OfficeLarge	50%
Restaurant	RestaurantFastFood	100%
Retail	RetailStandAlone	10%
" "	RetailLarge	75%
" "	RetailStripMall	5%
" "	RetailMixedUse	10%
Grocery Store	Grocery	100%

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Non-Refrigerated Warehouse	Warehouse	100%
Refrigerated Warehouse	RefrigWarehouse	N/A
Schools	SchoolPrimary	60%
" "	SchoolSecondary	40%
Colleges	OfficeSmall	5%
" "	OfficeMedium	15%
" "	OfficeMediumLab	20%
" "	PublicAssembly	5%
" "	SchoolSecondary	30%
" "	ApartmentHighRise	25%
Hospitals	Hospital	100%
Hotel/Motels	HotelSmall	100%

4.3 Per-Unit Energy Impacts Results

Energy savings per square foot are presented in Table 12 and Table 13. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 0.004 therms/yr to 0.008 therms/yr for the ApartmentHighRise prototype building, depending on climate zone. Per-unit savings for the first year are expected to range from 0.007 therms/yr to 0.012 therms/yr for the HotelSmall prototype building. The difference in energy savings between the two prototype models is due to the different DHW draw profiles assumed by CBECC-Com for the Hotel/Motel Guest Room and High-Rise Residential Living Spaces. No electricity or peak demand savings result from either prototype model, since the only electrical load associated with the Standard Design DHW system (pumps) remains constant.

Table 12: First-Year Energy Impacts Per Square Foot – ApartmentHighRise

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	0.008	1.848
2	N/A	N/A	0.007	1.708
3	N/A	N/A	0.007	1.707
4	N/A	N/A	0.007	1.604
5	N/A	N/A	0.007	1.707
6	N/A	N/A	0.006	1.548

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
7	N/A	N/A	0.006	1.547
8	N/A	N/A	0.006	1.487
9	N/A	N/A	0.006	1.505
10	N/A	N/A	0.006	1.495
11	N/A	N/A	0.006	1.521
12	N/A	N/A	0.006	1.601
13	N/A	N/A	0.006	1.467
14	N/A	N/A	0.006	1.541
15	N/A	N/A	0.004	1.128
16	N/A	N/A	0.007	1.810

Table 13: First-Year Energy Impacts Per Square Foot – HotelSmall

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	0.012	2.981
2	N/A	N/A	0.011	2.775
3	N/A	N/A	0.011	2.774
4	N/A	N/A	0.011	2.617
5	N/A	N/A	0.011	2.774
6	N/A	N/A	0.010	2.533
7	N/A	N/A	0.010	2.532
8	N/A	N/A	0.010	2.438
9	N/A	N/A	0.010	2.465
10	N/A	N/A	0.010	2.446
11	N/A	N/A	0.010	2.482
12	N/A	N/A	0.011	2.611
13	N/A	N/A	0.010	2.398
14	N/A	N/A	0.010	2.513
15	N/A	N/A	0.007	1.857
16	N/A	N/A	0.012	2.924

5. Cost and Cost Effectiveness

5.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years. The proposed measure applies only to new construction buildings and does not apply to additions or alterations.

5.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in 2023 present value dollars in Table 14 and Table 15. The energy cost savings in nominal dollars is presented in Appendix G.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. This measure does not result in electricity or peak demand savings because the only electrical load associated with the Standard Design DHW system (pumps) remains constant.

Table 14: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – ApartmentHighRise

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$0.00	$0.16	$0.16
2	$0.00	$0.15	$0.15
3	$0.00	$0.15	$0.15
4	$0.00	$0.14	$0.14
5	$0.00	$0.15	$0.15
6	$0.00	$0.14	$0.14
7	$0.00	$0.14	$0.14
8	$0.00	$0.13	$0.13
9	$0.00	$0.13	$0.13
10	$0.00	$0.13	$0.13
11	$0.00	$0.14	$0.14
12	$0.00	$0.14	$0.14
13	$0.00	$0.13	$0.13
14	$0.00	$0.14	$0.14
15	$0.00	$0.10	$0.10
16	$0.00	$0.16	$0.16

Table 15: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – HotelSmall

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$0.00	$0.27	$0.27
2	$0.00	$0.25	$0.25
3	$0.00	$0.25	$0.25
4	$0.00	$0.23	$0.23
5	$0.00	$0.25	$0.25
6	$0.00	$0.23	$0.23
7	$0.00	$0.23	$0.23
8	$0.00	$0.22	$0.22
9	$0.00	$0.22	$0.22
10	$0.00	$0.22	$0.22
11	$0.00	$0.22	$0.22
12	$0.00	$0.23	$0.23
13	$0.00	$0.21	$0.21
14	$0.00	$0.22	$0.22
15	$0.00	$0.17	$0.17
16	$0.00	$0.26	$0.26

5.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

Incremental first costs were estimated from RSMeans Data (RSMeans Online 2020). California statewide cost indices were calculated using the RSMeans cost indices for representative cities in each climate zone, weighted by the forecasted building areas applicable to this measure in each climate zone. Costs were estimated on a per-unit basis (i.e., costs for a single DWHR device), such that the unit costs can be easily multiplied by the number of units required in each prototype model. The unit costs for installing a DWHR device in the ApartmentHighRise and HotelSmall prototype buildings are assumed to be equal. Design costs are not included in the incremental first cost, per the Energy Commission's guidance.

The quantity of DWHR devices required for each prototype building are assumed to be one device per four residential units (i.e., hotel guestroom or apartment). The ApartmentHighRise prototype model has 75 apartment units, which results in 19 DWHR units. The HotelSmall prototype model has 77 guestrooms, which results in 20 DWHR units. The per-unit costs (Table 16) were multiplied by the number of units required and divided by prototype model areas to arrive at costs per area (Table 17 and Table 18).

Table 16: Incremental First Costs per unit

Item	Labor per unit [$]	Material per unit [$]	Total per unit [$]
DWHR unit, ¾" supply, 4" waste	$449	$736	**$1,185**

Table 17: Incremental First Costs – ApartmentHighRise

Item	Quantity [#]	Labor [$]	Material [$]	Total [$]	Area [ft^2]	Total per Area [$/ft^2]
DWHR unit, 0.75" supply, 4" waste	19	$8,524	$13,985	$22,509	93,632	$0.24

Table 18: Incremental First Costs – HotelSmall

Item	Quantity [#]	Labor [$]	Material [$]	Total [$]	Area [ft^2]	Total per Area [$/ft^2]
DWHR unit, 0.75” supply, 4” waste	20	$8,972	$14,721	$23,693	42,554	$0.56

5.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-Year period of analysis. This measure covers horizontal and vertical DWHR, but this calculation focuses on vertical. Product life is 30 to 50 years, which exceeds the lifecycle period. With no moving parts, no maintenance is required during the lifecycle period, so lifetime incremental maintenance cost is $0.00.

5.5 Cost-Effectiveness Results

The Statewide CASE Team investigated the feasibility of a primary prescriptive requirement for shower DWHR in nonresidential buildings. The Statewide CASE Team found that shower DWHR is not cost effective and changed this proposal to reflect a compliance option instead of a prescriptive requirement

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The incremental first cost and incremental maintenance costs over the 15-Year period of analysis were included. The TDV energy cost savings from natural gas savings were also included in the evaluation. Neither the design costs nor the incremental costs of code compliance verification were included.

According to the Energy Commission’s definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

The 2019 Statewide CASE Team performed energy simulations involving multiple different DWHR configurations (i.e., equal flow, unequal flow to the fixture, and unequal flow to the water heater) in two residential prototype models (2,700, and 6,960 ft^2). The 6,960 ft^2 model represented a multifamily building with four showers connected to a single DWHR device in an unequal flow to the shower configuration. Although the DHW draw profiles used in the 6,960 ft^2 multifamily model are slightly different than those in the ApartmentHighRise and HotelSmall models, they are both derived from same DHW draw profile schedules used by CBECC-Res (Kruis, et al. 2017). The 2019 Statewide CASE Team also assumed an unequal flow to the shower configuration for the 6,960 ft^2 model because it represents the most common configuration for multifamily buildings. Therefore, the energy savings of DWHR in the ApartmentHighRise and HotelSmall models were expected to be similar to those estimated for the 6960 ft^2 multifamily model.

However, a few notable differences in the nonresidential analysis negatively impact the cost-effectiveness of shower DWHR relative to the multifamily analysis performed by the 2019 Statewide CASE Team. Firstly, the 2019 Statewide CASE Team assumed a 15-Year period of analysis because it was a residential code measure. The energy and cost analysis supporting this proposal assumes a 15-year period of analysis because this measure applies to nonresidential buildings. Assuming costs and performance are similar to residential shower DWHR, benefit-to-cost ratios are anticipated to be approximately half of those reported in the 2019 CASE report, because benefits are reduced by half due to halving the analysis period. In addition to the difference in analysis periods, the nonresidential analysis assumes a lower DWHR effectiveness (42 percent compared to 46 percent) and a higher incremental measure cost ($1,184.67 per unit compared to $771.28). The 2019 analysis also assumed only shower water would flow through the DWHR device, whereas the nonresidential analysis assumes water from showers, baths, and faucets flows through the DWHR.

Results of the per-unit cost-effectiveness analyses are presented in Table 19 and Table 20 for new construction ApartmentHighRise and HotelSmall, respectively. The proposed measure was not found to be cost effective in any climate zone. The B/C ratio ranges from 0.42 to 0.68 for ApartmentHighRise and from 0.30 to 0.48 for HotelSmall.

Table 19: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction – ApartmentHighRise

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.16	$0.240	0.68
2	$0.15	$0.240	0.63
3	$0.15	$0.240	0.63
4	$0.14	$0.240	0.59
5	$0.15	$0.240	0.63
6	$0.14	$0.240	0.57
7	$0.14	$0.240	0.57
8	$0.13	$0.240	0.55
9	$0.13	$0.240	0.56
10	$0.13	$0.240	0.55
11	$0.14	$0.240	0.56
12	$0.14	$0.240	0.59
13	$0.13	$0.240	0.54
14	$0.14	$0.240	0.57
15	$0.10	$0.240	0.42
16	$0.16	$0.240	0.67

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 20: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction – HotelSmall

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.27	$0.557	0.48
2	$0.25	$0.557	0.44
3	$0.25	$0.557	0.44
4	$0.23	$0.557	0.42
5	$0.25	$0.557	0.44
6	$0.23	$0.557	0.40
7	$0.23	$0.557	0.40
8	$0.22	$0.557	0.39
9	$0.22	$0.557	0.39
10	$0.22	$0.557	0.39
11	$0.22	$0.557	0.40
12	$0.23	$0.557	0.42
13	$0.21	$0.557	0.38
14	$0.22	$0.557	0.40
15	$0.17	$0.557	0.30
16	$0.26	$0.557	0.47

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

6. First-Year Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team found that shower DWHR is not cost effective and changed this proposal to reflect a compliance option instead of a prescriptive requirement. Therefore, there would be no claimable statewide savings associated with the proposed revisions to the compliance options available in the performance path. The energy cost impacts presented in this section represent the potential savings that could result from DWHR installed in nonresidential buildings. The impacts analysis assumes DWHR is installed on all nonresidential new construction showering facilities. The impacts analysis also assumes that all nonresidential buildings with DWHR are served by gas-fired DHW systems. Gas-fired DWH systems are the current Standard Design for the ApartmentHighRise and HotelSmall prototype models. CBECC-Com does not currently support electric DHW systems serving more than eight residential units. However, if the electrification of appliances continues to proliferate throughout California, it is reasonable to assume that at least some of the newly constructed DHW systems serving nonresidential showering facilities would utilize central electric heat pump water heaters (HPWH). Therefore, although no electricity savings were estimated, the Statewide CASE Team expects some of the energy savings would result in electricity savings, in addition to gas savings.

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 4.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-Year energy cost savings represent the energy cost savings over the entire 15-Year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 21 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 21: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (PV$ million in 2023)
1	0.061	N/A	N/A	0.00	$0.02
2	0.363	N/A	N/A	0.00	$0.08
3	1.649	N/A	N/A	0.02	$0.39
4	0.851	N/A	N/A	0.01	$0.19
5	0.167	N/A	N/A	0.00	$0.04
6	0.961	N/A	N/A	0.01	$0.21
7	1.011	N/A	N/A	0.01	$0.22
8	1.336	N/A	N/A	0.01	$0.28
9	2.105	N/A	N/A	0.02	$0.44
10	1.184	N/A	N/A	0.01	$0.24
11	0.247	N/A	N/A	0.00	$0.05
12	1.390	N/A	N/A	0.01	$0.31
13	0.472	N/A	N/A	0.00	$0.09
14	0.258	N/A	N/A	0.00	$0.05
15	0.181	N/A	N/A	0.00	$0.03
16	0.081	N/A	N/A	0.00	$0.02
TOTAL	12.317	N/A	N/A	0.12	$2.65

a. First-year savings from all buildings completed statewide in 2023.

6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 22 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 658 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 22: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (MMTherms/ yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Nonresidential Drain Water Heat Recovery	0	0	0.12	658	658

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/MMTherms.

6.3 Statewide Water Use Impacts

The proposed code change would not result in water savings. DWHR devices do not impact the time for hot water to arrive at the shower.

6.4 Statewide Material Impacts

DWHR introduces a new piece of equipment into the DHW distribution system. Therefore, adoption of this measure would result in an increase of copper based on the number of units installed statewide. The DWHR device would replace part of the drain pipe, which are typically constructed of steel or PVC. The length of pipe replaced by the DWHR device would be the length of the DWHR device, which is typically 48 inches. DWHR devices typically weigh approximately 20 pounds and are constructed almost entirely of copper. Some DWHR devices may be installed in buildings to improve energy efficiency, but since this proposal is not requiring DWHR, no significant change in material use is expected.

Table 23: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/yr)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Copper	I	20 pounds	

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from all buildings completed statewide in 2023.

6.5 Other Non-Energy Impacts

Non-energy impacts associated with DWHR include an effective increase in heating capacity provided to the fixtures by pre-heating the cold water. This impact could potentially reduce the required capacity of the water heater, but plumbing designers often size the heater without accounting for the impacts of DWHR as an added safety factor. Increased property value is another potential impact, since DWHR effectively reduces the building's water heating costs.

7. Proposed Revisions to Code Language

7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions: Recommends new or revised definitions for the following terms:

DRAIN WATER HEAT RECOVERY (DWHR) consists of a heat exchanger that transfers heat from warm effluent in waste piping to cold supply water in a domestic or service water system.

SUBCHAPTER 2 ALL OCCUPANCIES – MANDATORY REQUIREMENTS FOR THE MANUFACTURE, CONSTRUCTION AND INSTALLATION OF SYSTEMS, EQUIPMENT AND BUILDING COMPONENTS

SECTION 110.3 – MANDATORY REQUIRMENTS FOR SERIVCE WATER-HEATING SYSTEMS AND EQUIPMENT

(c)5. Service water heaters in state buildings. Any newly constructed building constructed by the State shall derive its service water heating from a system that provides at least 60 percent of the energy needed for service water heating from site solar energy or recovered energy, per the statutory requirement of California Public Resources Code Section 25498. Recovered energy includes drain water heat recovery (DWHR) devices installed on domestic or service water systems.

7.3 Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below.

2.1.1 Manufacturer Certification for Equipment, Products, and Devices

In nonresidential buildings, the following are examples of products that must be certified by the manufacturer:

- Air economizers
- Airflow measurement apparatus – forced air systems
- Airflow measurement apparatus – ventilation systems

- Air-to-air heat pump systems
- Economizer fault detection and diagnostics
- Intermittent mechanical ventilation systems
- Low-leakage air-handling unit
- Occupant-controlled smart thermostats
- Demand-responsive control systems
- <u>Drain water heat recovery devices</u>

7.4 ACM Reference Manual

5. Building Descriptors Reference

5.9.1.1 System Loads and Configuration

Water Heating System Configuration	
Applicability	All water heating systems
Definition	The configuration and layout of the water heating system including the number of water heaters; the size, location, length and insulation of distribution pipes; <u>drain water heat recovery devices and related equipment and controllers;</u> recirculation systems and pumps; and any other details about the system that would affect the energy model.
Units	Data structure
Input Restrictions	None
Standard Design	For healthcare facility spaces, the same as Proposed. For high-rise residential buildings, the rules in the Residential ACM Reference Manual shall be followed. For all other spaces, the standard design shall have one gas storage water heater if any of the spaces have a Space Water Heating Fuel Type of Gas (from Appendix 5.4A), and the standard design building will have ~~on~~ <u>an</u> electric water heater if ~~the~~ any of the spaces have a Space Water Heating Fuel Type of Electric.

<u>Drain Water Heat Recovery Effectiveness</u>

Applicability	Water heating systems with a drain water heat recovery (DWHR) system
Definition	The DWHR effectiveness is the ratio between the actual heat transfer rate and the maximum possible heat transfer rate. Equal to the CSA- or IAPMO-rated effectiveness.
Units	Unitless
Input Restrictions	As designed
Standard Design	The Standard Design for buildings with less than four showers on a shared drain line has no DWHR system. The Standard Design for buildings with four or more showers with a shared drain line has DWHR devices on each shower where one exists in the proposed design.

7.5 Compliance Manuals

There are no proposed changes to the compliance manuals.

7.6 Compliance Documents

There are no proposed changes to the compliance documents.

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Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards will be in effect (2023). The projected nonresidential new construction forecast that would be impacted by the proposed code change in 2023 is presented in Table 24. This section describes how the Statewide CASE Team developed these estimates.

The Energy Commission Building Standards Office provided the nonresidential construction forecast, which is available for public review on the Energy Commission's website: https://www.energy.ca.gov/title24/participation.html.

The construction forecast presents total floorspace of newly constructed buildings in 2023 by building type and climate zone. The building types included in the Energy Commissions' forecast are summarized in Table 11. This table also identifies the prototypical buildings that were used to model the energy use of the proposed code changes. This mapping was required because the building types the Energy Commission defined in the construction forecast are not identical to the prototypical building types that the Energy Commission requested that the Statewide CASE Team use to model energy use. This mapping is consistent with the mapping that the Energy Commission used in the Final Impacts Analysis for the 2019 code cycle (California Energy Commission 2018).

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, would remain constant. See Table 25 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 26 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that some buildings would be impacted by the proposal. Table 27 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone. The proposed requirement applies to new construction buildings that contain multiple showers. Therefore, new construction Hotel/Motel and the residential portions of the College building types (dormitories) are impacted in all climate zones.

Table 24: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)											
	Small Office	Large Office	Restaurant	Retail	Grocery Store	Non-Refrig erated Ware house	Refrig erated Ware house	Schools	Colleges	Hospitals	Hotel/ Motels	TOTAL
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	N/A	0.05	0.06
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.20	N/A	0.31	0.36
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.87	N/A	1.43	1.65
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.44	N/A	0.74	0.85
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.09	N/A	0.14	0.17
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.45	N/A	0.85	0.96
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.40	N/A	0.91	1.01
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.64	N/A	1.18	1.34
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.21	N/A	1.80	2.11
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.62	N/A	1.03	1.18
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.17	N/A	0.20	0.25
12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.79	N/A	1.19	1.39
13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.34	N/A	0.39	0.47
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.13	N/A	0.22	0.26
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	0.17	0.18
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.05	N/A	0.07	0.08
TOTAL	0	0	0	0	0	0	0	0	6.50	0	10.69	12.32

Table 25: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1

Building Type	2020 Forecast (Million Square Feet) [A]	Distribution Excluding Miscellaneous Category [B]	Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]	Revised 2020 Forecast (Million Square Feet) [E] = A + C
Small Office	0.036	7%	0.010	0.046
Large Office	0.114	21%	0.031	0.144
Restaurant	0.015	3%	0.004	0.020
Retail	0.107	20%	0.029	0.136
Grocery Store	0.029	5%	0.008	0.036
Non-Refrigerated Warehouse	0.079	15%	0.021	0.101
Refrigerated Warehouse	0.006	1%	0.002	0.008
Schools	0.049	9%	0.013	0.062
Colleges	0.027	5%	0.007	0.034
Hospitals	0.036	7%	0.010	0.046
Hotel/Motels	0.043	8%	0.012	0.055
Miscellaneous **[D]**	0.145	---	0.000	0.145
TOTAL	0.686	100%	0.147	0.83370

Table 26: Percent of Floorspace Impacted by Proposed Measure, by Building Type

Building Type Building sub-type	Composition of Building Type by Subtypes[a]	Percent of Square Footage Impacted[b]	
		New Construction	Existing Building Stock (Alterations)[c]
Small Office		N/A	N/A
Restaurant		N/A	N/A
Retail		N/A	N/A
Stand-Alone Retail	10%	N/A	N/A
Large Retail	75%	N/A	N/A
Strip Mall	5%	N/A	N/A
Mixed-Use Retail	10%	N/A	N/A
Food		N/A	N/A
Non-Refrigerated Warehouse		N/A	N/A
Refrigerated Warehouse		N/A	N/A
Schools		N/A	N/A
Small School	60%	N/A	N/A
Large School	40%	N/A	N/A
College		N/A	N/A
Small Office	5%	N/A	N/A
Medium Office	15%	N/A	N/A
Medium Office/Lab	20%	N/A	N/A
Public Assembly	5%	N/A	N/A
Large School	30%	N/A	N/A
High-Rise Apartment	25%	100%	N/A
Hospital		N/A	N/A
Hotel/Motel		100%	N/A
Offices		N/A	N/A
Medium Office	50%	N/A	N/A
Large Office	50%	N/A	N/A

a. Presents the assumed composition of the main building type category by the building subtypes. All 2022 CASE Reports assumed the same percentages of building subtypes.

b. When the building type is composed of multiple subtypes, the overall percentage for the main building category was calculated by weighing the contribution of each subtype.

c. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

Table 27: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	9%	N/A
2	9%	N/A
3	9%	N/A
4	9%	N/A
5	9%	N/A
6	8%	N/A
7	10%	N/A
8	7%	N/A
9	7%	N/A
10	7%	N/A
11	7%	N/A
12	7%	N/A
13	6%	N/A
14	6%	N/A
15	8%	N/A
16	6%	N/A

a. Percent of existing floorspace that will be altered during the first year the 2022 standards are in effect.

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 MMTCO2e per GWh. The Summary Table from eGRID 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per MMTherms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – \$106/MTCO$_2$e.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

Introduction

The purpose of this appendix is to present proposed revisions to the California Building Energy Code Compliance software for nonresidential buildings (CBECC- Com) along with the supporting documentation that the Energy Commission staff, and the technical support contractors would need to approve and implement the software revisions.

Technical Basis for Software Change

Drain water heat recovery (DWHR) is a technology used to conserve energy for water heating. The technology utilizes a heat exchanger to transfer heat from warm drain water to cold supply water. This proposal introduces a compliance option for shower DWHR in nonresidential buildings. Shower DWHR modeling is currently supported in the latest version of the compliance software for nonresidential buildings (CBECC-Com 2019) but is only enabled for High-Rise Residential Living Spaces. This software specification proposes adding DWHR modeling capabilities for other nonresidential space functions with showers.

Description of Software Change

Background Information for Software Change

DWHR was adopted into Title 24, Part 6 during the 2019 code cycle as a compliance option and an alternative prescriptive pathway for single family and low-rise multifamily buildings. The 2019 Statewide CASE Team tested multiple DWHR products in laboratories to develop algorithms for estimating energy savings in residential buildings. The software development team for the California Simulation Engine (CSE) incorporated these algorithms into the 2019 residential compliance modeling software (CBECC-Res 2019).

Existing CBECC- Com Modeling Capabilities

Shower DWHR is currently supported in the latest version of the nonresidential compliance modeling software (CBECC-Com 2019) as a compliance option for domestic water heating systems serving High-Rise Residential Livings Spaces. CBECC-Com utilizes the California Simulation Engine (CSE) to model domestic hot water energy in residential space types. Two residential space functions are available in CBECC-Com: High-Rise Residential Livings Spaces and Hotel/Motel Guestrooms.

CBECC-Com currently supports shower DWHR modeling for only High-Rise Residential Living Spaces, using the model developed for CSE.

Summary of Proposed Revisions to CBECC-Com

This proposal introduces a compliance option for shower DWHR in nonresidential buildings. To support this measure, the compliance software should enable the same DWHR modeling capabilities that are already supported for High-Rise Residential Livings Spaces for all other space functions that have showers. Currently, the only space function in CBECC-Com that has showers (other than High-Rise Residential Livings Spaces) is Hotel/Motel Guest Room. Therefore, this software specification proposes adding shower DWHR modeling capabilities to the Hotel/Motel Guest Room space function in CBECC-Com, using the same model that currently supports DWHR modeling in High-Rise Residential Livings Spaces.

User Inputs to CBECC-Com

The same inputs that currently exist for DWHR serving High-Rise Residential Livings Spaces should be added for Hotel/Motel Guestrooms and any other residential space functions with showers that may be added to CBECC-Com in future releases. Currently, the Dwelling Unit Data tab for Hotel/Motel Guestrooms has no input options and displays the following text: “Data in this tab only applies to High-Rise Residential Livings Spaces” (Figure 6).

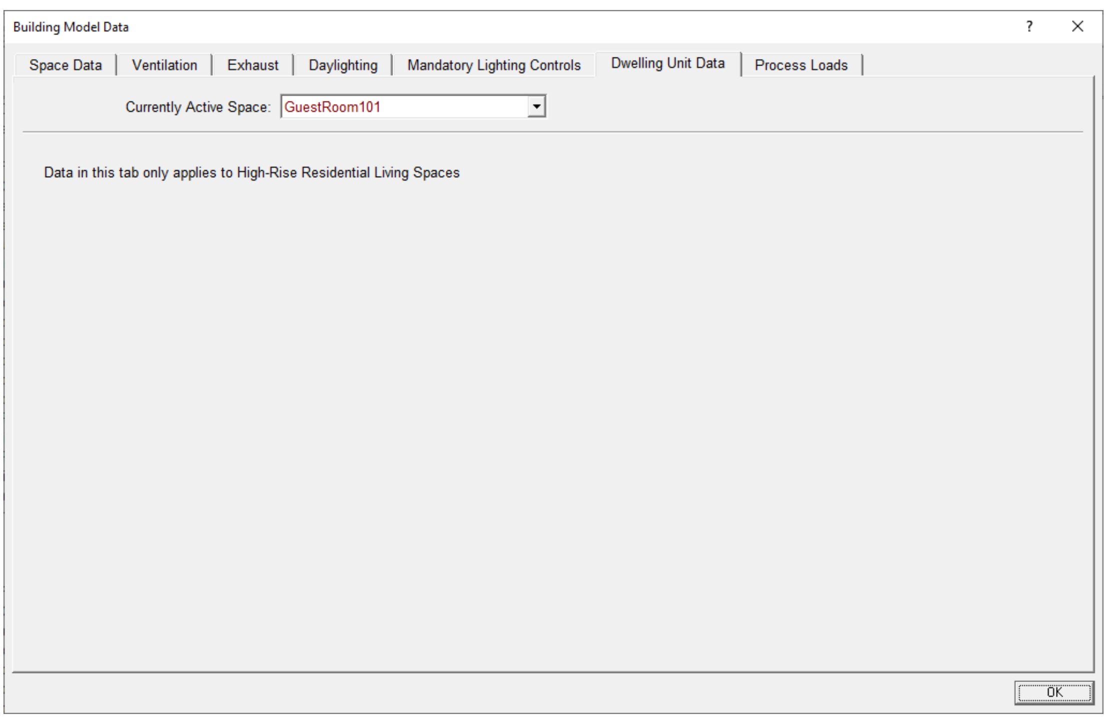

Figure 6: Dwelling unit data for hotel/motel guestrooms (CBECC-Com 2019)

The Dwelling Unit Data tab for Hotel/Motel Guestrooms would be modified to reflect inputs similar to those currently shown on the Dwelling Unit Data tab for High-Rise Residential Living Spaces (Figure 7).

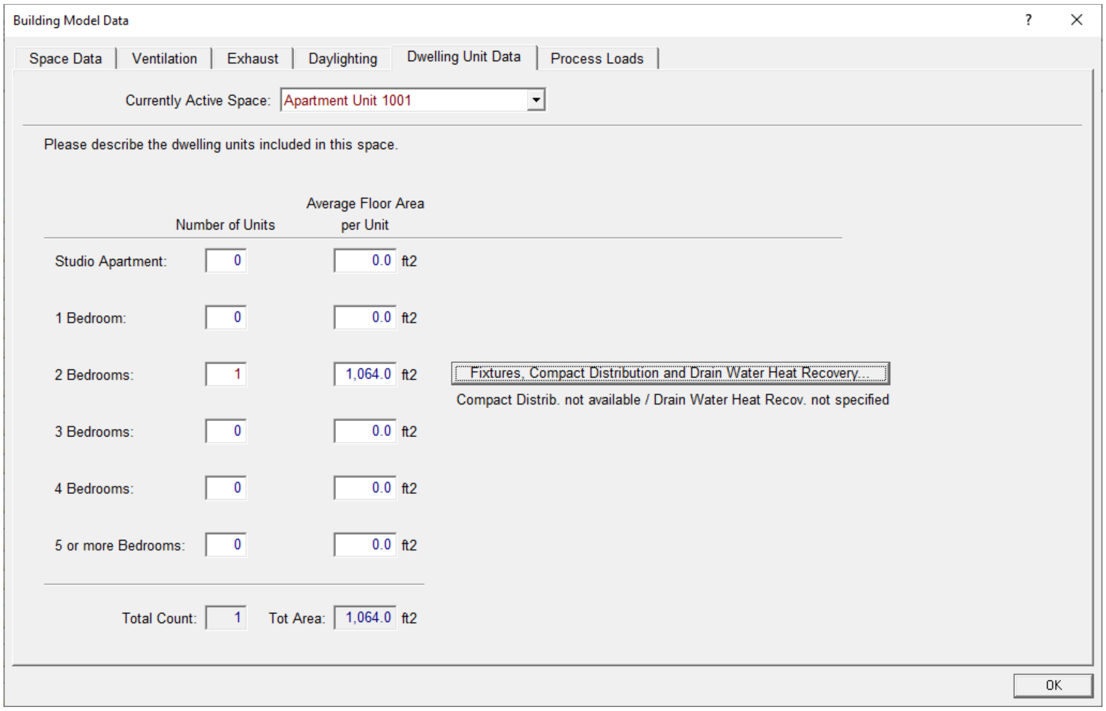

Figure 7: Dwelling unit data for high-rise residential living spaces (CBECC-Com 2019).

The Dwelling Unit Data tab for Hotel/Motel Guestrooms should display input fields that are relevant to this particular space function. Instead of “Number of Units”, the Dwelling Unit Data tab for Hotel/Motel Guestrooms should provide inputs for “Number of Showers”, which should default to a value of 1.

The “Fixtures, Compact Distribution, and Drain Water Heat Recovery” button would be enabled if “Number of Showers” is set to at least 1. Clicking this button should bring up a screen with the same input options that are currently available for High-Rise Residential Living Spaces (Figure 8).

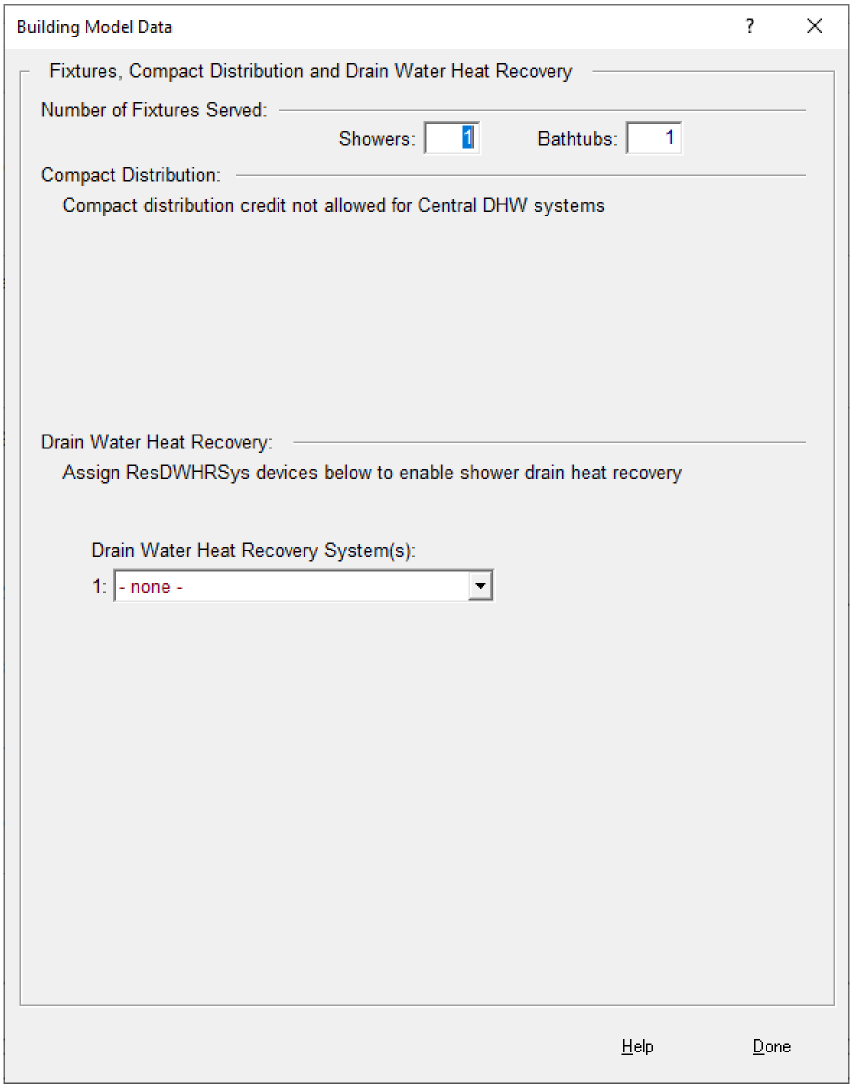

Figure 8: Fixtures, compact distribution and drain water heat recovery screen.

Selecting "Create new ResidentialDrainWaterHeatRecoverySystem (and apply only here)" should bring up a screen similar to Figure 9, below.

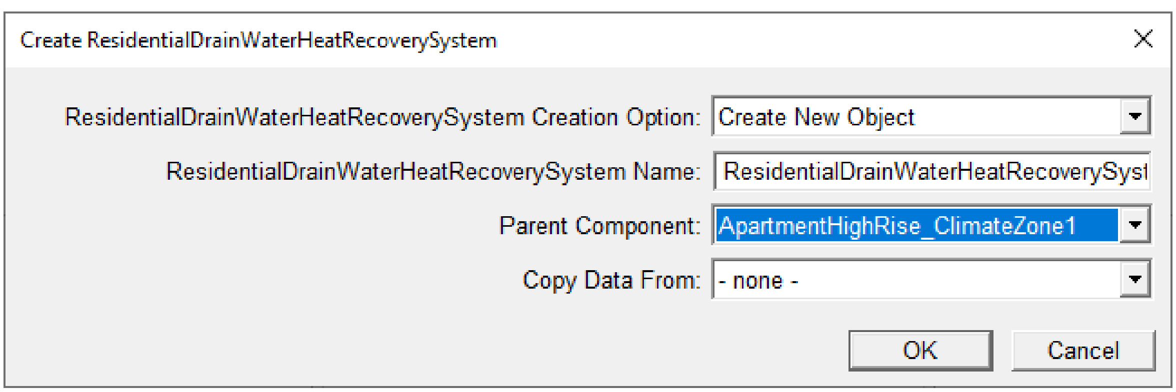

Figure 9: Create new ResidentialDrainWaterHeatRecoverySystem screen.

After completing the inputs on the screen shown in Figure 9 and selecting “OK”, a subsequent screen would be displayed with inputs as shown in Figure 10, below. The “CSA Rated Efficiency” input would default to the current minimum allowable efficiency of 42 percent. The label for this input should be changed to “CSA or IAPMO Rated Effectiveness”, to clearly indicate that both CSA and IAPMO effectiveness ratings are supported.

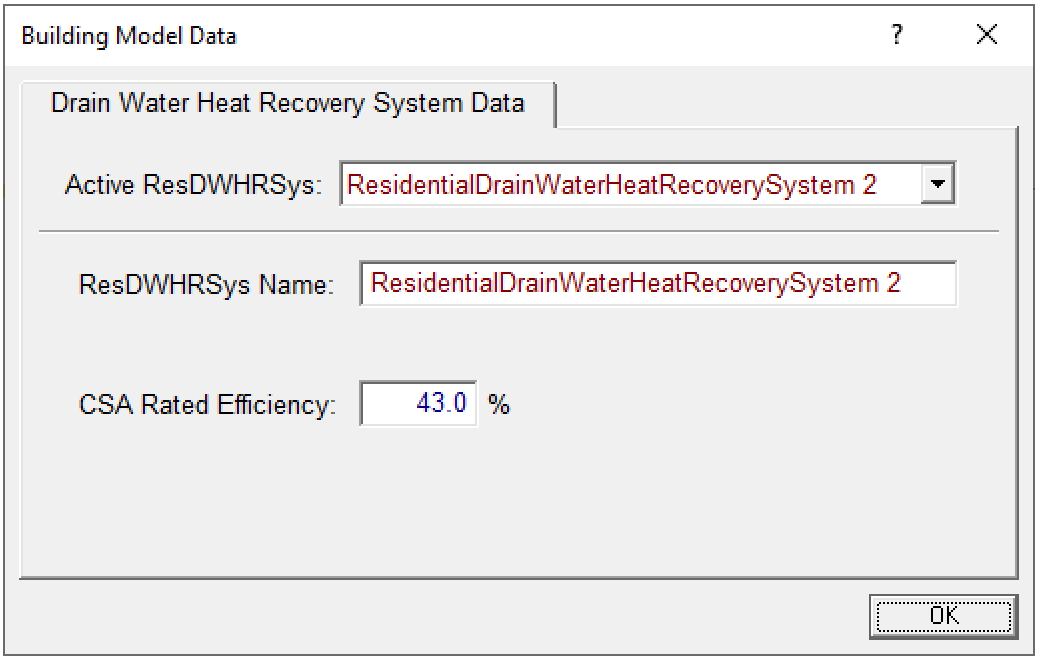

Figure 10: Drain water heat recovery system data screen.

Once the user selects “OK” on this screen, the screen would close and the screen shown in Figure 8 would display again, now showing additional input options for quantity of shower drains (which defaults to 1) and “Warmed Water Feeds… Water Heater” (which default to checked). Selecting “Done” on this screen finalizes the DWHR specification and returns to the Dwelling Unit Data screen.

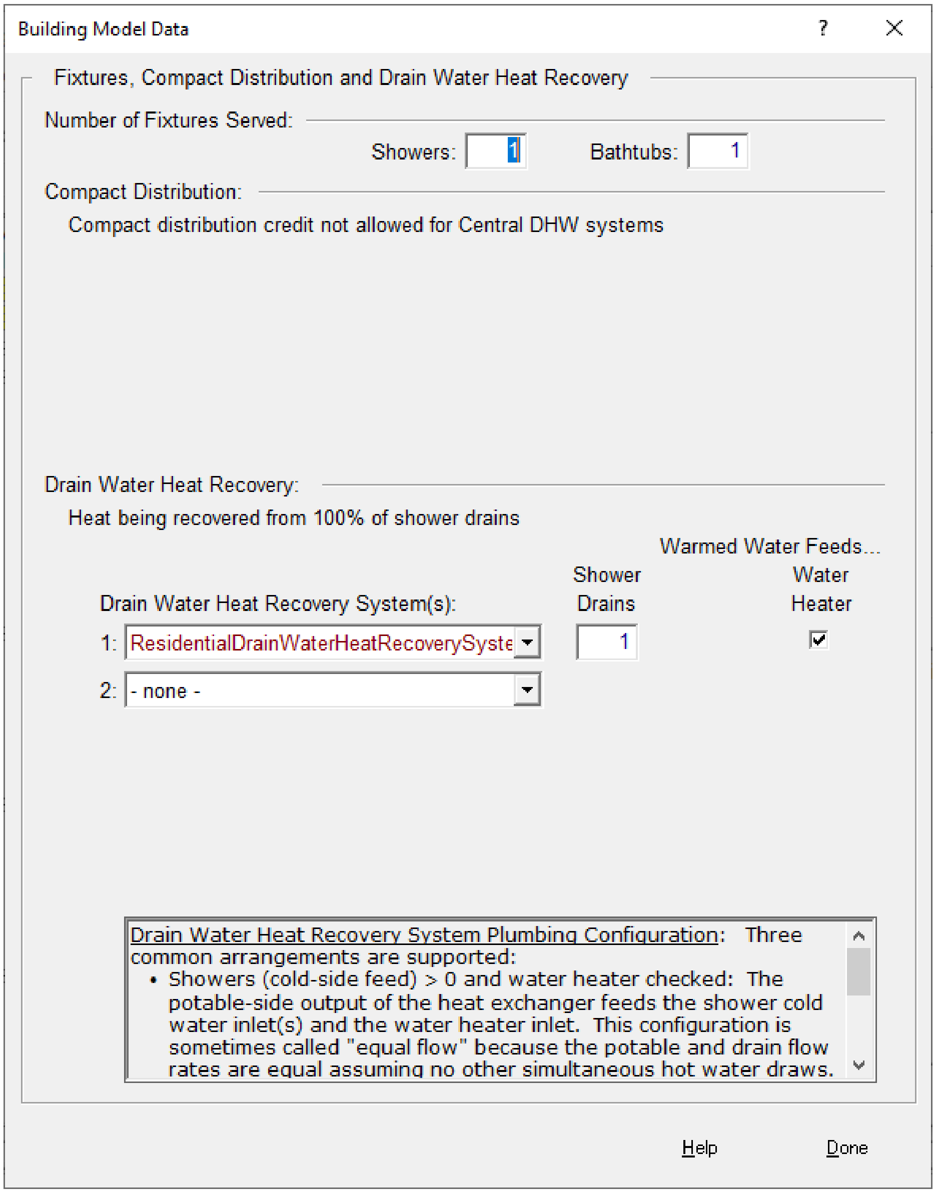

Figure 11: Fixtures, compact distribution and drain water heat recovery screen after creating and selecting DWHR system(s).

Table 28 lists the CBECC-Com user inputs relevant to DWHR.

Table 28: User Inputs Relevant to Drain Water Heat Recovery

Input Screen	Variable Name	Data Type	Units	User Editable	Recommended Label
Dwelling Unit Data	Number of Showers	Integer	None	Yes	Number of Showers
Fixtures, Compact Distribution, and Drain Water Heat Recovery	Number of Fixtures Served – Showers	Integer	None	Yes	Showers:
Fixtures, Compact Distribution, and Drain Water Heat Recovery	Number of Fixtures Served – Bathtubs	Integer	None	Yes	Bathtubs:
Fixtures, Compact Distribution, and Drain Water Heat Recovery	Drain Water Heat Recovery System(s)	String	None	Yes	Drain Water Heat Recovery System(s)
Fixtures, Compact Distribution, and Drain Water Heat Recovery	Shower Drains	Integer	None	Yes	Shower Drains
Fixtures, Compact Distribution, and Drain Water Heat Recovery	Warmed Water Feeds… Water Heater	Check	None	Yes	Warmed Water Feeds Water Heater
Drain Water Heat Recovery System Data	ResDWHRSys Name	String	None	Yes	ResDWHRSys Name
Drain Water Heat Recovery System Data	CSA Rated Efficiency	Float	%	Yes	CSA or IAPMO Rated Effectiveness

Simulation Engine Inputs

EnergyPlus/California Simulation Engine Inputs

Figure 7 through Figure 11 and Table 28 provide recommended translation information for generating CSE inputs from CBECC-Com inputs. In CSE, DWHR is modeled using a single object: DHWHEATREC (Figure 12). The DHWHEATREC object is inserted directly below a DHWSYS (DHW System) object and includes fields for DWHR type (vertical/horizontal), number of fixtures draining, number of fixtures where cold water is preheated, whether the pre-heated water feeds the water heater, and the heat exchanger's rated effectiveness. This object is repeated for below the DHWSYS object for each zone that is served by a DWHR device. Proposed default parameter values for the DHWHEATREC object are summarized in Table 29.

```
DHWSYS   "dhwsys-Apartment Unit 1001 DU2"
   wsCentralDHWSYS = "dhwsys-ResidentialDHWSystem"
   wsDayUse = DHW2BRd
   wsWF = 1                         // frac
   wsSDLM = 1.17719
   wsDSM = 1
   wsShowerCount = 1
   wsBathCount = 1

   DHWHEATREC   "dwhrsys1-dhwsys-Apartment Unit 1001 DU2"
      wrType = "Vertical"
      wrCountFXDrain = 1
      wrFeedsWH = "Yes"
      wrCSARatedEF = 0.42           // frac
```

Figure 12: DWHR object in CSE input file.

Table 29: Default Parameter Values for CSE DWHR Object

Objects Modified	Parameter Names	Default Parameter Value
DHWHEATREC	wrType	Vertical
" "	wrCountFXDrain	1
" "	wrCountFXCold	1
" "	wrFeedsWH	No
" "	wrCSARatedEF	0.42

Alternate Configurations

The existing CBECC-Com DWHR modeling capability is limited to single DWHR units serving single DHW systems/zones. The software currently does not allow a single DWHR device to capture drain water heat from multiple zones and serve those zones the pre-heated cold water. This capability is necessary for simulating common DWHR designs, where DWHR devices are installed on drain lines serving multiple showers, and pre-heated supply water is routed to each of the showers.

Horizontal or sloped DWHR configurations should also be supported. One DWHR manufacturer makes a device specifically designed and rated for horizontal configurations. However, some DWHR designs use vertical DWHR devices installed on a sloped angle, to accommodate space limitations. A vertical DWHR device can still provide substantial heat recovery, albeit at a reduced effectiveness. Since vertical DWHR devices are rated according to CSA test procedures, which require a vertical configuration, the CSE-rated effectiveness would not be accurate for the same device installed in a sloped configuration. Instead, the device should be tested according to the IAPMO IGC 346 test procedure, which was specifically developed for rating sloped and horizontal DWHR devices. In the absence of an IAPMO-rated effectiveness, a generic algorithm can be used to predict the performance of vertical DWHR devices installed in sloped configurations (Grant et al, 2019). CBECC-Com could utilize this algorithm to estimate effectiveness of sloped DWHR devices by requiring slope angle as an additional input.

Simulation Engine Output Variables

CSE generates hourly simulation results to CSV files during analysis. Analysts can use these hourly simulation results to debug a building energy model. Variables of particular interest in this case would include:

- DHWMETER
- wsTInlet
- wsUse

DHWMETER is a user-defined "device" that records water consumption as simulated by CSE. The data accumulated by DHWMETERs can be reported at hourly, daily, monthly, and annual intervals by using REPORTs and EXPORTs of type DHWMTR. wsTInlet is the cold (mains) water temperature supplying this DHWSYS. DHWHEATER supply water temperature wsTInlet adjusted (increased) by any DHWHEATREC recovered heat. wsUSE is the hourly hot water use (at the point of use).

Compliance Report

CBECC-Com generates a Title 24 Compliance Report that presents the results of the building's compliance analysis. Tables K5 and K6 in the detailed section of the report summarize the DHW equipment and Multi-family Hotel/Motel Central DHW System Details (Figure 13). A new table should be included below K6 that summarizes the DWHR devices included in the model. The new table, K7, should include all of the inputs summarized in Table 29.

K5. DHW EQUIPMENT SUMMARY										
1	2	3	4	5	6	7	8	9	10	11
DHW Name	Heater Element Type	Tank Type	Qty	Tank Vol (gal)	Rated Input (kBtu/h)	Efficiency	Tank Insulation R-value (Int/Ext)	Standby Loss Fraction	Heat Pump Type	Tank Location or Ambient Condition
NonResBaseWaterHeater	Gas	Storage	1	40.06	40	UEF: 0.56	NA	SBLF: NA	NA	NA
ResidentialWaterHeater	Gas	Storage	1	100.00	250	Thrml. Eff.: 0.800	/		NA	Unconditioned

K6. MULTI-FAMILY HOTEL/MOTEL CENTRAL DHW SYSTEM DETAILS											§ 110.3
1.	2.	3.	4.	5.	6.	7.		8.			
						Recirculating Pump		Piping Length			
System Name	Configuration	Type	Qty in System	Central Dist. Type	Unit Dist. Type	Efficiency	BHP	Plenum	Outside	Buried	Add ½" Insulation (HERS)
ResidentialDHWSystem	"DHW System"	Central	1	Demand Control (Standard Design for new construction)	NA	0.60	(kW)				

Figure 13: Summary table describing DHW systems and equipment in the Title 24 compliance report

Description of Changes to ACM Reference Manual

Changes to the ACM Reference Manual are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

Drain Water Heat Recovery Type	
Applicability	Water heating systems with a drain water heat recovery (DWHR) system
Definition	A DWHR system consists of a double wall heat exchanger that recovers heat from the effluent in waste piping and uses it to preheat water in a domestic or service water-heating system in order to reduce water heating and energy usage.
Units	List On-demand Equal Flow, On-demand Unequal Flow, Tank, or None
Input Restrictions	None
Standard Design	The Standard Design for [non-cost-effective building types] has no DWHR system. The Standard Design for [cost-effective building types] has an On-demand Equal Flow DWHR system.

Drain Water Heat Recovery Effectiveness	
Applicability	Water heating systems with a drain water heat recovery (DWHR) system
Definition	The DWHR effectiveness is the ratio between the actual heat transfer rate and the maximum possible heat transfer rate. Equal to the CSA rated efficiency.
Units	Unitless
Input Restrictions	As designed
Standard Design	The Standard Design has no DWHR system.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. Table 30 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in Table 30 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Table 30: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plumbing designer	• Design a domestic hot water system meeting code • Coordinate with design team regarding space, penetrations, access, features and pathway of plumbing system	Meet project goals with consideration including alternative measures used in the performance approach to achieve compliance	N/A	Include example riser diagrams in the manual for different system configurations. Similar to what's in manual for dual-recirc loop. If in CASE report, the Energy Commission could easily put in manual too.
Energy Consultant/ Modeler	Support design team to provide guidance on energy code requirements on methods to show compliance	Utilize compliance method determined by team to be the best method for the project and complete compliance documentation (certificate of compliance NRCC)	N/A	N/A
Energy Commission	Provide compliance tools and forms supporting code requirements and options	N/A	Would require changes to CBECC-Com.	N/A

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Owner	• Inform design team of budget and goals for the building. • Be aware of building feature design in terms of maintenance on ongoing costs	Determines budget and building features of design as is supported by design team.	• Need to think about how DWHR would be maintained. CASE team has gotten feedback that no maintenance is required from mfrs, but Gina thinks it's been a bigger issue & should ask designers & building maintenance staff for project where this is installed. & may be a difference between condos and rentals. • Adding a solar thermal and drain water HR requirement would add significant cost to the project.	N/A
Contractors	• Bid and install building features per the design documents (plan set/specifications/compliance documents) • Keep project in budget and on time • Build and warranty work • Provide certificate of installation compliance documents (NRCI) to support installed features meet the promise of the plan set / specifications / compliance documents (NRCC) • Coordinate acceptance testing/HERS verification of system	• Provide submittals to design team to confirm installed features meet plan set/specifications/compliance documents. • May support cost engineering exercise to keep project on budget, in which designed features may be revised	• Would likely want to VE a DWHR out of a design because it's new technology to them & they'd be concerned about liability issues. Even though it's not complicated, it's just piping. • Hearing concern about build up in device impacting long term EE. May be more perception than reality.	Would need to help contractors understand installation practices.

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plans examiner	Confirm that plan set and compliance documents are supporting each other, and that compliance is achieved	• Understand that the DWHR system is an energy compliance feature • Confirm all building codes are met with all building design features such as DWHR on plan set/specifications/compliance documents	DWHR would be a new building feature in which they have little experience and may have concerns on installation and access to these systems.	N/A
Building Inspector	• Confirm building is meeting plan set/specifications/compliance documents • Confirm NRCI and any NRCA forms have been completed and make available to building owner	N/A	N/A	N/A

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including: cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted one stakeholder meetings for nonresidential drain water heat recovery via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting. Such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
Multifamily and Nonresidential Water Heating Utility-Sponsored Stakeholder Meeting	Thursday, October 3, 2019	https://title24stakeholders.com/event/multifamily-water-heating-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[5] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. The Statewide CASE Team was particularly interested in reaching out to individuals that could speak to the challenges

[5] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/."

and opportunities for installing DWHR in a variety of nonresidential scenarios, including non-shower applications, such as commercial kitchen and laundry applications. The Statewide CASE Team conducted outreach to and received feedback from DWHR technology manufacturers, building engineers, and researchers. Outreach for the nonresidential DWHR code change proposal was conducted in coordination with outreach for the multifamily DWHR code change proposal.

Manufacturers

Seven manufacturers were identified and contacted: EcoDrain, EcoInnovation/ThermoDrain, RenewABILITY Energy Inc., ReTHERM Energy Systems, Swing Green, Watercycles, and Sharc International. Of those contacted, the Statewide CASE Team conducted phone interviews with representatives from EcoDrain, EcoInnovation, RenewABILITY, and Swing Green. Topics discussed with these individuals included:

- Real and potential nonresidential DWHR applications
- Cost-effectiveness, including configurations to maximize effectiveness
- Product pricing, availability, and US manufacturing
- Available metrics for calculating effectiveness, such as u-factor and surface area, CSA-rated effectiveness, and CSA test and IAPMO procedures.
- Available studies on retail cost, product offerings, markets, or cost effectiveness

Systems Designers and Building Engineers

Two building systems designers and one nonresidential building contractor known to have installed DWHR systems were contacted for their insight. Of those contacted, one mechanical engineer at Arup was consulted regarding DWHR design considerations during the construction process.

Researchers

The Statewide CASE Team interviewed researchers at Pacific Gas and Electric's Applied Technology Services Lab, The Food Service Technology Center (Fishnik), and NegaWatt Consulting to understand recent developments in DWHR technology, current limitations of the technology, potential data sources for determining cost effectiveness, and other research sources.

Appendix G: Energy Cost Savings Using Nominal Dollars

In Section 5.2, the energy cost savings of the proposed code changes over the 15-Year period of analysis are presented in 2023 present value dollars. This appendix presents energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis, but the time value of money is not included so the results are not discounted.

These values represent the maximum potential nominal dollar cost savings assuming a DWHR prescriptive requirement is adopted for all ApartmentHighRise and Hotel/Motel Guest Rooms.

Table 31. Nominal Energy Cost Savings Over 15-Year Period of Analysis - Per Square Foot - New Construction - ApartmentHighRise

Climate Zone	15/30-Year TDV Electricity Cost Savings (Nominal $)	15/30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15/30-Year TDV Energy Cost Savings (Nominal $)
1	$0.00	$0.23	$0.23
2	$0.00	$0.22	$0.22
3	$0.00	$0.22	$0.22
4	$0.00	$0.20	$0.20
5	$0.00	$0.22	$0.22
6	$0.00	$0.20	$0.20
7	$0.00	$0.20	$0.20
8	$0.00	$0.19	$0.19
9	$0.00	$0.19	$0.19
10	$0.00	$0.19	$0.19
11	$0.00	$0.19	$0.19
12	$0.00	$0.20	$0.20
13	$0.00	$0.19	$0.19
14	$0.00	$0.19	$0.19
15	$0.00	$0.14	$0.14
16	$0.00	$0.23	$0.23

Table 32. Nominal Energy Cost Savings Over 15-Year Period of Analysis - Per Square Foot - New Construction - HotelSmall

Climate Zone	15/30-Year TDV Electricity Cost Savings (Nominal $)	15/30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15/30-Year TDV Energy Cost Savings (Nominal $)
1	$0.00	$0.38	$0.38
2	$0.00	$0.35	$0.35
3	$0.00	$0.35	$0.35
4	$0.00	$0.33	$0.33
5	$0.00	$0.35	$0.35
6	$0.00	$0.32	$0.32
7	$0.00	$0.32	$0.32
8	$0.00	$0.31	$0.31
9	$0.00	$0.31	$0.31
10	$0.00	$0.31	$0.31
11	$0.00	$0.31	$0.31
12	$0.00	$0.33	$0.33
13	$0.00	$0.30	$0.30
14	$0.00	$0.32	$0.32
15	$0.00	$0.23	$0.23
16	$0.00	$0.37	$0.37